Research Note

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INFILTRATION AND SOIL EROSION ON COOLWATER RIDGE, IDAHO

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ABSTRACT

The infiltration and erosion caused by simulated rainfall were measured on a granitic subalpine ridge in north-central Idaho. Erosion was closely correlated with the amount of exposed soil. Infiltration was not highly correlated with any single factor. However, three soil properties (organic-matter content, clay content, and moisture-holding capacity at 20-centimeter tension) in combination were found to be good predictors of infiltration.

Coolwater Ridge is a deteriorated subalpine range at the northern boundary of the Nezperce National Forest in central Idaho. Present vegetation is mostly low-value forbs--for example, knotweed (Polygonum spp.). Soils consist of decomposed granite, typical of actively eroding sites on the Idaho batholith.

This area was selected as one of the study sites of a major study designed to determine how soil and plant cover characteristics influence infiltration and erosion on summer range in the Intermountain Region. During the summer of 1963, simulated rain tests were made at 15 sites to determine infiltration and erosion potentials. Selected cover characteristics and soil properties were measured and related to infiltration and erosion.

The study plots had an average slope gradient of 33 percent. The surface inch of soil on the plots contained an average of 57 percent sand, 11 percent clay, and 10 percent organic matter.

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METHODS

Simulated rain was applied to infiltrometer plots (0.1 milacre in size) at a constant intensity of 5 inches per hour for 30 minutes, using the rainfall simulator described by Dortignac.[2] Resultant runoff was measured and all soil washed from the plots was collected, oven-dried, and weighed.

Both areal cover density and air-dry weight of vegetation were measured on each plot. The areal cover provided by vegetation, litter, and stone, was measured with a point analyzer,[3] using first strikes at 100 equally spaced points. Vegetation and litter were removed separately after the rain test; then, this material was air-dried and weighed.

A number of soil properties were measured, including bulk density, moisture content at 20- and 60-centimeter tension, texture, aggregation, and organic matter content. The data were analyzed by multiple regression techniques to develop prediction equations relating infiltration and erosion to soil and cover characteristics.

EROSION

The amount of soil eroded under the impact of 2.5 inches of simulated rain ranged from 0.1 to 27.7 pounds per milacre, with an average of 9.6 pounds and a standard deviation of 9.3 pounds per milacre. These weights were more highly correlated with percentage of soil surface exposed to direct raindrop impact (percentage of first strikes of the point analyzer on bare soil) than with any other measured variable.

The following equation explains 63 percent of the variance in eroded soil and has a standard error-of-estimate of 5.9 pounds per milacre:

$$\hat{Y} = 27.75X^2,$$

where:

$\hat{Y}$ = estimated erosion (pounds per milacre),

X = proportion of the soil surface not protected by plants, litter, or stone.

The curve defined by this equation is plotted in figure 1, along with the data. No significant increase in explained variance was obtained by adding any other variable in multiple regression. None of the other measured variables, including slope gradient, exerted significant influence on the weight of soil eroded beyond that due to the proportion of bare soil.

INFILTRATION

The plots retained an average of 0.97 inch of water during the 30-minute rainfall test. Variation in amount of water retained was not large, ranging from 0.60 to 1.38 inches with a standard deviation of 0.24 inch. The difference between applied rain and the measured runoff is the water retained by the plot. These values were used as the dependent variable characterizing infiltration.

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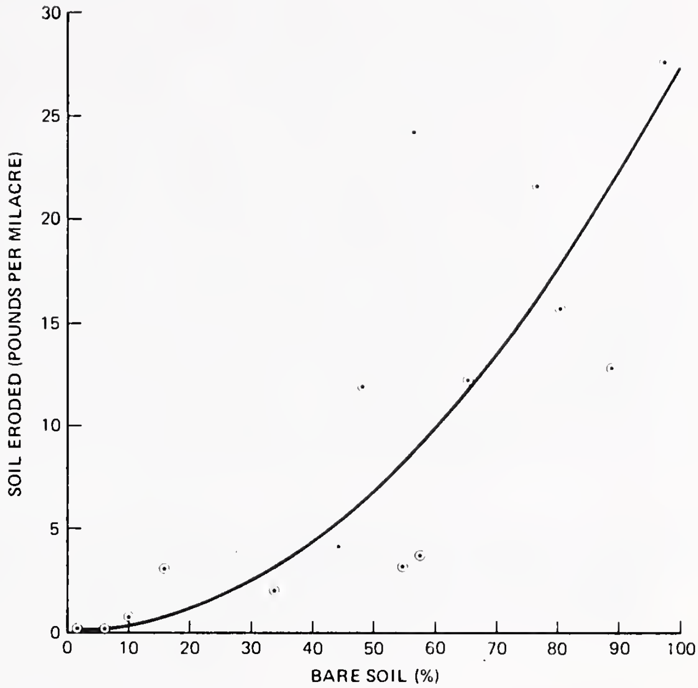
[2]Dortignac, E. J. Design and operation of Rocky Mountain infiltrometer. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Sta. Pap. 5, 68 pp. 1951.

[3]Levy, E. B., and E. A. Madden. The point method of pasture analysis. New Zealand J. Agr. 46: 267-279. 1933.

Figure 1.--Pounds per milacre of soil eroded by 2.5 inches of simulated rainfall in relation to percentage of the soil surface exposed to direct raindrop impact.



Only three measured site factors were significantly correlated (at the 5 percent level) with water retained:

Air-dry weight of litter ($r = -0.52$);
Bulk density of the surface inch of soil ($r = +0.51$);
Clay content of the surface inch of soil ($r = +0.51$).

The inverse relation between litter weight and water retained and the positive relation between soil-bulk density and water retained were contrary to results of similar studies on other areas. Apparently some process is operating to reverse the expected relations between litter weight and water retained, and between soil-bulk density and water retained. Consequently, a series of multiple regression analyses were made to delve further into these apparent anomalies. An equation that explained 73 percent of the variance and has a standard error-of-estimate of 0.14 inch was developed:

$$\hat{Y} = -1.394 + 0.058X_1 + 0.933X_2 - 0.026X_1X_2,$$

where:

$\hat{Y}$ = estimated inches of water retained during the 30-minute simulated rain test,

X_1= moisture content by volume of the surface 2-inches of soil at 20-centimeter tension,

X_2= the ratio of organic matter to clay content in the surface inch of soil.

The following inferences may be drawn from this equation, graphically presented in figure 2:

1. The amount of water retained increases as the moisture-holding capacity at 20-centimeter tension increases unless the surface inch of soil contains about twice as much organic matter as clay.

2. A high ratio of organic matter relative to clay limits infiltration. This effect is particularly noticeable at higher moisture-holding capacities.

This adverse effect of organic matter is inconsistent with the current concept that organic matter favors development of porous and permeable soil. However, in this sandy soil, there is little opportunity for organic matter to aggregate the soil and render it more permeable. We hypothesize that organic matter contains constituents that coat the mineral soil particles and render them water repellent. The greater the organic matter content, the more extensive and effective are these water-repellent coatings. Clay, which has a much greater surface area per unit weight than sand, tends to dilute and reduce effectiveness of the water-repellent constituents of organic matter. Thus, infiltration is inversely related to the ratio of organic matter to clay.

The correlation between litter weight and water retained is negative on this study site because of the significant positive correlation between litter weight and soil organic matter content (r = +0.71). Similarly, the correlation between soil bulk density and water retained is positive because of the strong negative correlation between soil bulk density and organic matter content (r = -0.85).

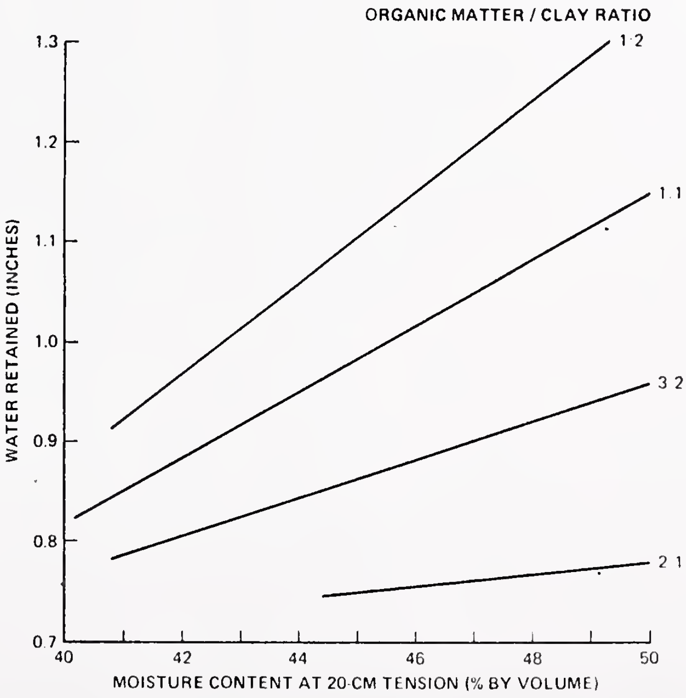


Figure 2.--Inches of water retained during a 30-minute simulated rainstorm as a function of soil moisture content at 20-centimeter tension, and the ratio of organic matter to clay.

CONCLUSIONS

As generally reported for other areas where erosion has been studied, the amount of protective cover present is the dominant factor controlling erosion on Coolwater Ridge. On the basis of the few measurements made here, it appears that at least 90 percent of the soil surface should be protected from direct raindrop impact by plants, litter, or stone to prevent accelerated erosion on this highly-erodible granitic soil. Erosion under study conditions exceeded 1 pound per milacre on all plots with more than 10 percent bare soil (figure 1).

The surface soils on Coolwater Ridge tend to be water repellent. The degree of water repellency appears to be closely related to organic matter content or, more specifically, to the amount of organic matter that is not bound to clay particles. Organic matter apparently forms water-repellent coatings on the coarser soil particles. A similar phenomenon has been reported by DeBano and Krammes[4] in the southern California chaparral type where non-wettable layers are formed in coarse-textured soils as a result of fire.

This water repellency, whether fire-induced or not, severely limits infiltration in soils that otherwise would be highly permeable. It may pose a serious problem for watershed management and should be investigated further.

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[4]DeBano, L. F., and J. S. Krammes. Water repellent soils and their relations to wildfire temperatures. Bull. Int. Assoc. Sci. Hydrol. XI(2): 14-19. 1966.